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RELIABILITY AND MAINTAINABILITY EVALUATION OF THE TOWER CAB DIG--ETC(U)
DEC 80 A R MOSS, G C APOSTOLAKIS

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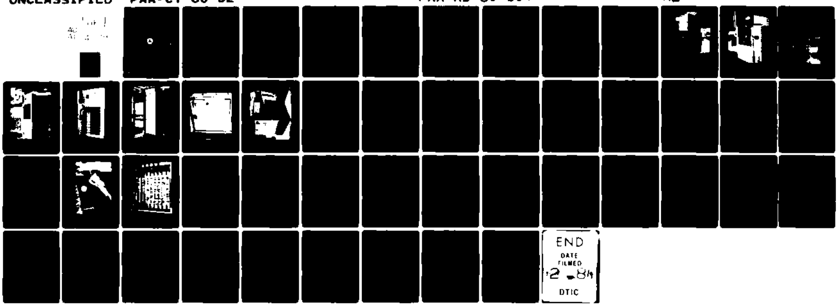

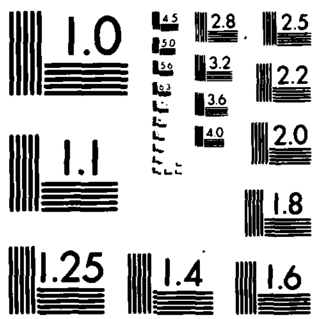

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RELIABILITY AND MAINTAINABILITY EVALUATION OF THE TOWER CAB DIGITAL DISPLAY SYSTEM

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LEVEL II

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DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA

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FINAL REPORT

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16. Abstract

A reliability and maintainability evaluation was performed on eight Tower Cab Digital Display (TCDD) systems located at four Florida air traffic control (ATC) facilities. Data were collected between August 25, 1979, and February 29, 1980. Analysis of these data showed that 21 chargeable hardware failures occurred (excluding the telephone lines). This corresponds to an overall system mean-time-between-failures (MTBF) of 1,001 hours and a mean-time-to-repair (MTTR) of 2.9 hours.

In addition to the chargeable hardware failures, many system outages which could be attributed to transitory, environmental, or undefined causes occurred. These outages included noisy telephone lines, frequent automatic restarts, and high ambient room temperatures.

The measured MTBF for a subset of the system was found to be lower than the corresponding predicted value. The 2.9-hour measured MTTR is considered excessive. Recommended actions for several design changes are included.

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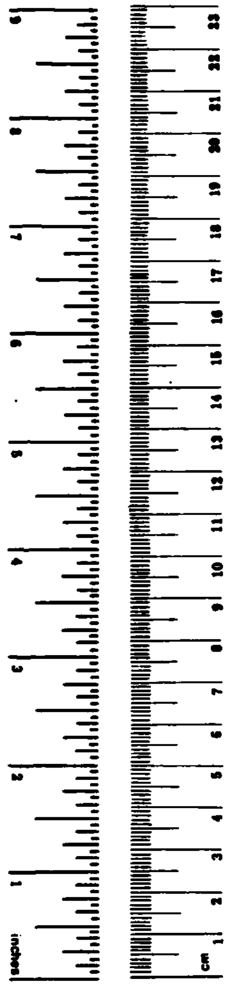
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

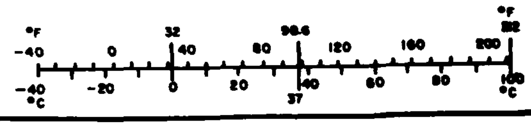
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The authors wish to express their appreciation to the FAA personnel at the Tampa, St. Petersburg, and Sarasota air traffic control facilities and to the personnel at MacDill Air Force Base for their assistance in this reliability and maintainability effort. The thoroughness, accuracy, and completeness of the data which they recorded and made available to the FAA Technical Center personnel have contributed materially to the integrity of this analysis.

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INTRODUCTION

PURPOSE.

This report summarizes the reliability and maintainability evaluation which was conducted on eight Tower Cab Digital Display (TCDD) systems installed at Tampa, St. Petersburg, Sarasota, and MacDill Air Force Base in Florida. Based on the data analyzed during this evaluation, mean-time-between-failure (MTBF) and mean-time-to-repair (MTTR) values were generated. The MTBF and MTTR values are figures of merit or numerical indexes of reliability and maintainability, respectively. These values were generated for each of the eight TCDD systems, the various units and equipment comprising the systems, and various combinations of the systems.

In addition to the MTBF and MTTR values, which are based upon chargeable hardware failures, this report also discusses the various system outages and problem areas caused by reasons other than chargeable failures. These include transitory malfunctions and outages as well as those due to environmental conditions, noisy telephone lines, and indeterminate causes.

BACKGROUND.

Each of the four facilities contains two TCDD systems. One system in each facility is used in the control tower cab for operational air traffic control. At the three facilities other than MacDill, the other TCDD system is used in the equipment room for maintenance; at MacDill, the other TCDD is used operationally for ground control approach (GCA).

Initially, all eight systems were to be evaluated during an official test period of 4 months; however, some were not used because of non-TCDD related causes. Consequently, the official reliability and maintainability evaluation covers only the four systems located at St. Petersburg and MacDill Air Force Base for the period January 7 to February 29, 1980. However, in order to extend the data base, all eight systems were analyzed from the time each system became operational until just prior to the start of the official test. The time intervals for which data were collected prior to the official test are as follows:

Tampa:	December 2-31, 1979
St. Petersburg:	October 26, 1979 - January 6, 1980
MacDill:	August 25, 1979 - January 6, 1980
Sarasota:	September 6 - December 31, 1979

SYSTEM DESCRIPTION

The TCDD provides a remote digital presentation of the air traffic situation generated by the Automated Radar Terminal System (ARTS) IIIA located at the Tampa terminal. This information is provided to the local tower cab at Tampa as well as to the remote tower cabs at St. Petersburg, Sarasota, and MacDill Air Force Base. At the Tampa, St. Petersburg, and Sarasota tower cabs, one TCDD system is used operationally while the other serves in a maintenance or monitoring capacity. At MacDill Air Force Base, both systems are used operationally, one in the tower cab and the other for ground approach control. Each TCDD system also provides capability for the tower controller to communicate with the ARTS IIIA for the purpose of entering, deleting, or updating flight data.

Each TCDD system consists of the following modules or units:

1. Display processor (unit 1)

2. Power supply chassis (unit 2)

3. Display (unit 3)

4. Two keyboards (unit 4)

5. Remote control panel (unit 5)

6. Two trackballs (unit 6)

7. Remote display buffer memory (RDBM)

The two keyboards and trackballs are not redundant units but are used in two controller positions for each operational system. The maintenance systems at Tampa, St. Petersburg, and Sarasota include only one each of these two units.

Figure 1 shows the display processor, the power supply chassis, and the display unit for a typical TCDD maintenance system. Figure 2 shows the display processor and power supply chassis for a typical tower cab installation. Figure 3 indicates how the display unit would appear in a tower cab installation. While the unit shown is not a TCDD, it is physically sufficiently similar to show how the display unit would appear mounted in the special yoke provided.

Figure 4 shows the remote control panel, keyboard, and trackball units in the equipment room; figure 5, the keyboard and trackball units mounted in the tower cab; and figure 6, the RDBM for a typical maintenance system in relation to the other equipment in the equipment room. Figure 7 gives a close-up view of the front panel of the RDBM.

In addition to the above seven types of units or modules which comprise the TCDD system proper, the telephone lines which convey data between the ARTS IIIA and the tower cabs and the modems in the tower cabs are also included in the TCDD system configuration from the standpoint of this reliability and maintainability evaluation. Figure 8 shows the RDBM and the Codex 8200 modem used in the tower cab system at Tampa. Figure 9 is a block diagram which shows how the eight systems located at the four air traffic control facilities interface with the ARTS IIIA at Tampa.

DATA COLLECTION, REDUCTION, AND ANALYSIS

DATA COLLECTION.

Data collection consisted of logging any event or situation which was different from the normal energized and operational status of the equipment. Such events included: shutdown of any equipment unit, preventive maintenance, hardware failures, engineering changes, and changes in system configuration.

This information was entered on standard Federal Aviation Administration (FAA) 6030.1 facility maintenance log forms for the three FAA facilities (Tampa, Sarasota, and St. Petersburg). A contractor's log form was used at MacDill Air Force Base as well as for recording additional data at the FAA facilities. The logged data included a complete history of every hardware failure as well as other malfunctions and outages including manual and automatic RDBM restarts.

DATA REDUCTION AND ANALYSIS.

From the equipment logs, each reported malfunction was analyzed to determine whether it was a chargeable failure. The criteria for chargeability are as follows:

1. The failure is independent; that is, it did not occur as a result of another failure or hardware modification.

2. The failure causes a loss or degradation of performance beyond specified or acceptable limits of the equipment unit (reliability element) in which it occurred.

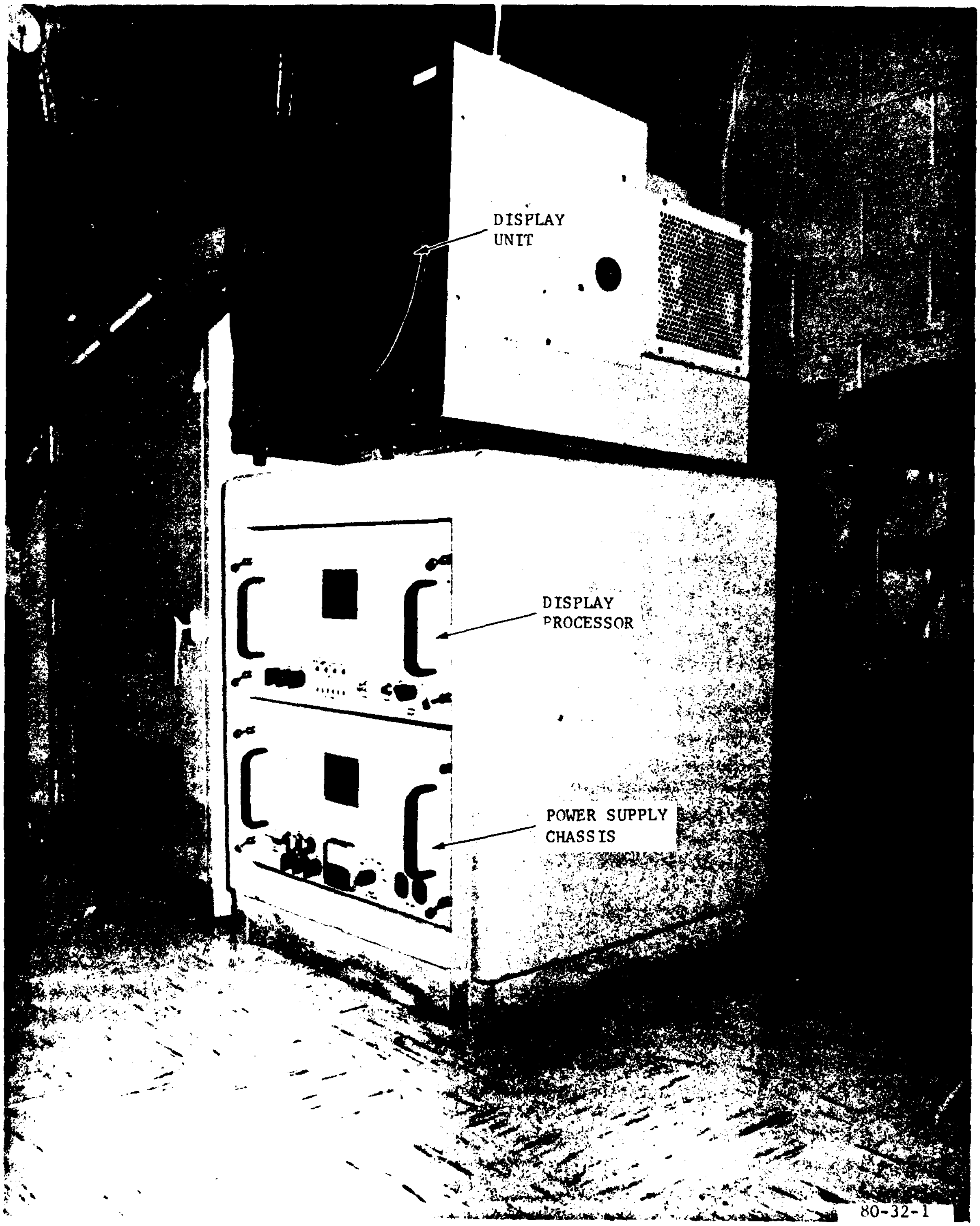

FIGURE 1. DISPLAY PROCESSOR, POWER SUPPLY CHASSIS, AND DISPLAY UNIT FOR TYPICAL TCDD MAINTENANCE SYSTEM

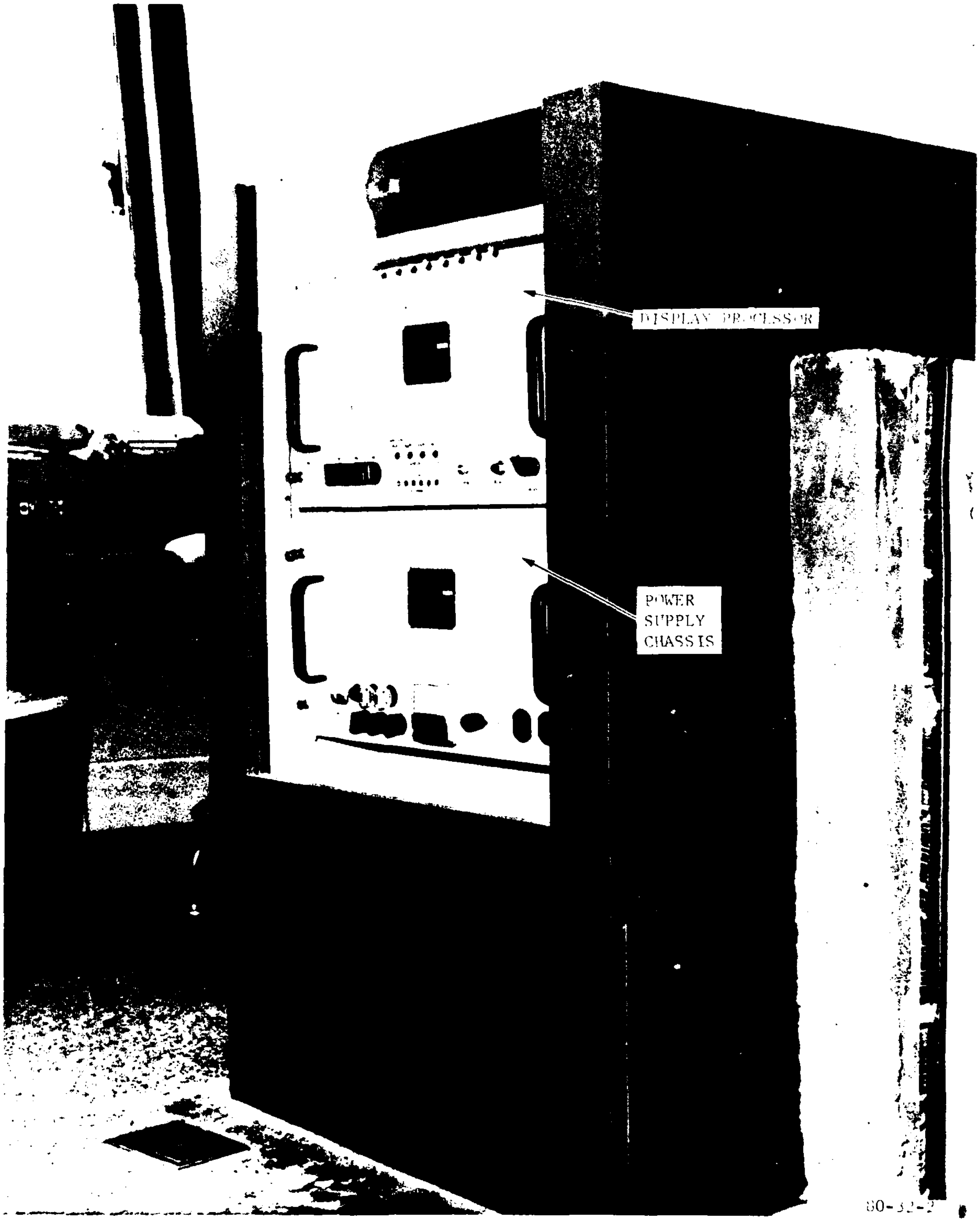

FIGURE 2. DISPLAY PROCESSOR AND POWER SUPPLY CHASSIS FOR TYPICAL TOWER CAB SYSTEM

FIGURE 3. TYPICAL TOWER CAB SHOWING YOKE MOUNTING FOR DISPLAY UNIT

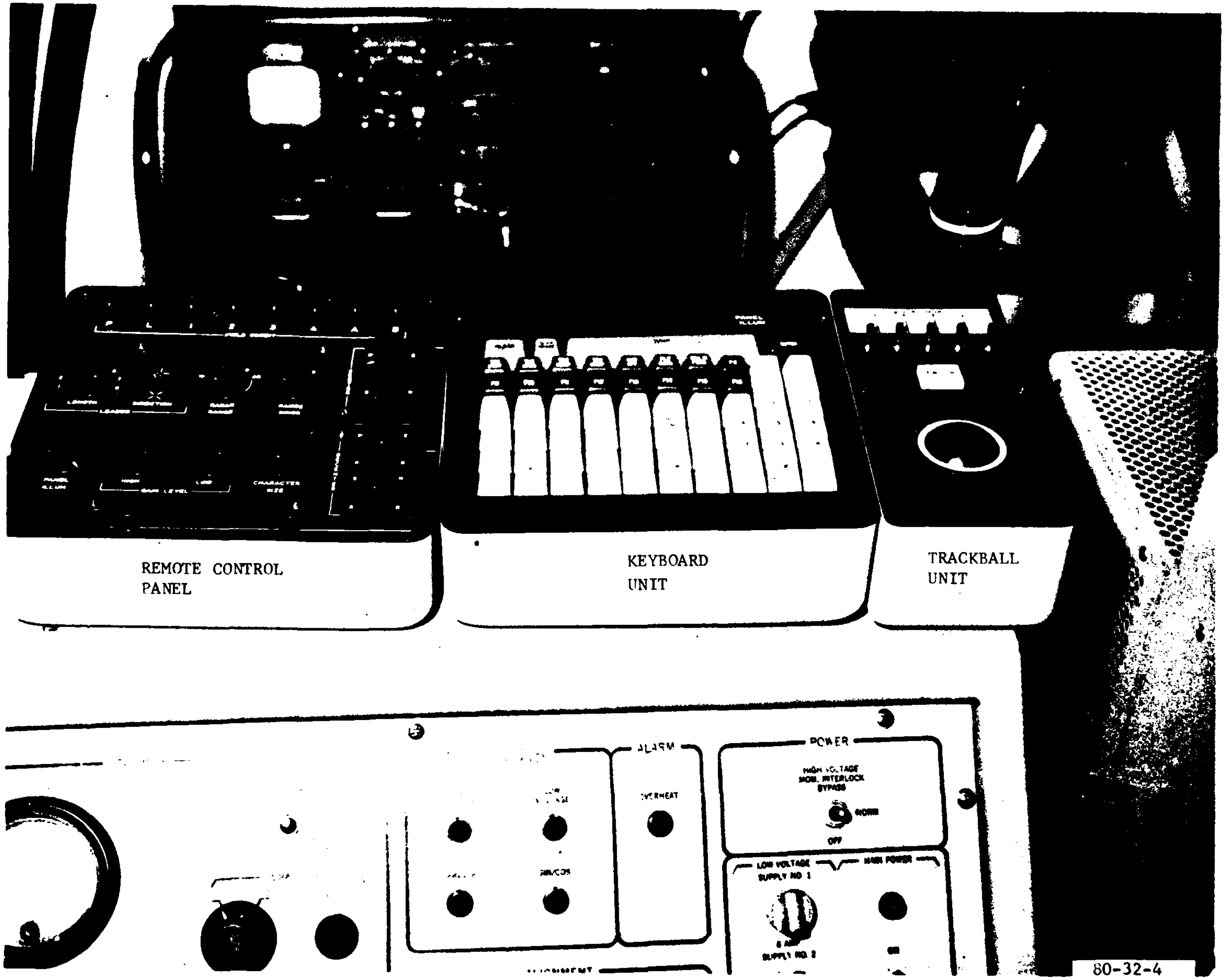

FIGURE 4. REMOTE CONTROL PANEL, KEYBOARD, AND TRACKBALL IN TCDD MAINTENANCE SYSTEM

FIGURE 5. KEYBOARD AND TRACKBALL IN TOWER CAB SYSTEM

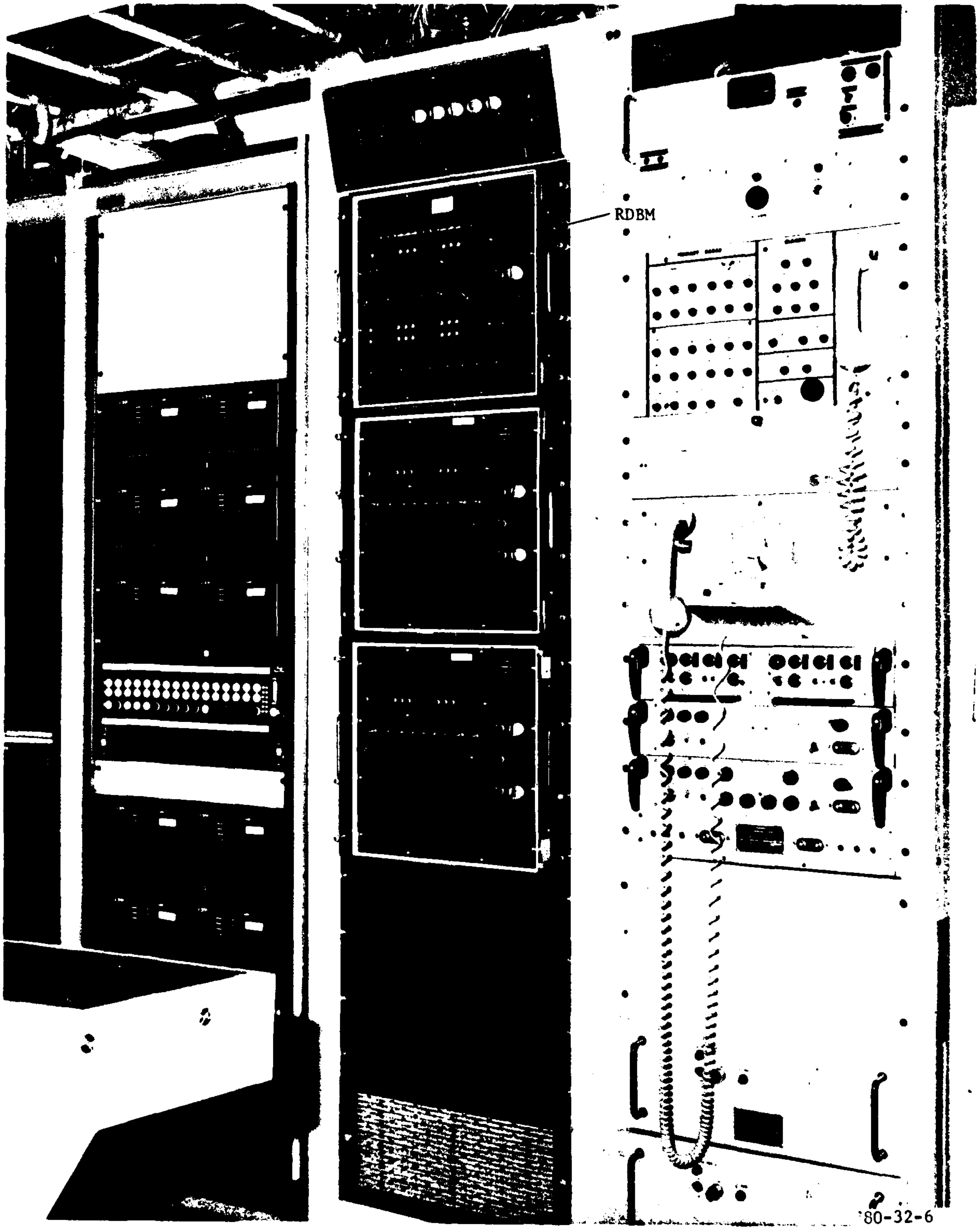

FIGURE 6. RDBM IN TCDD MAINTENANCE SYSTEM

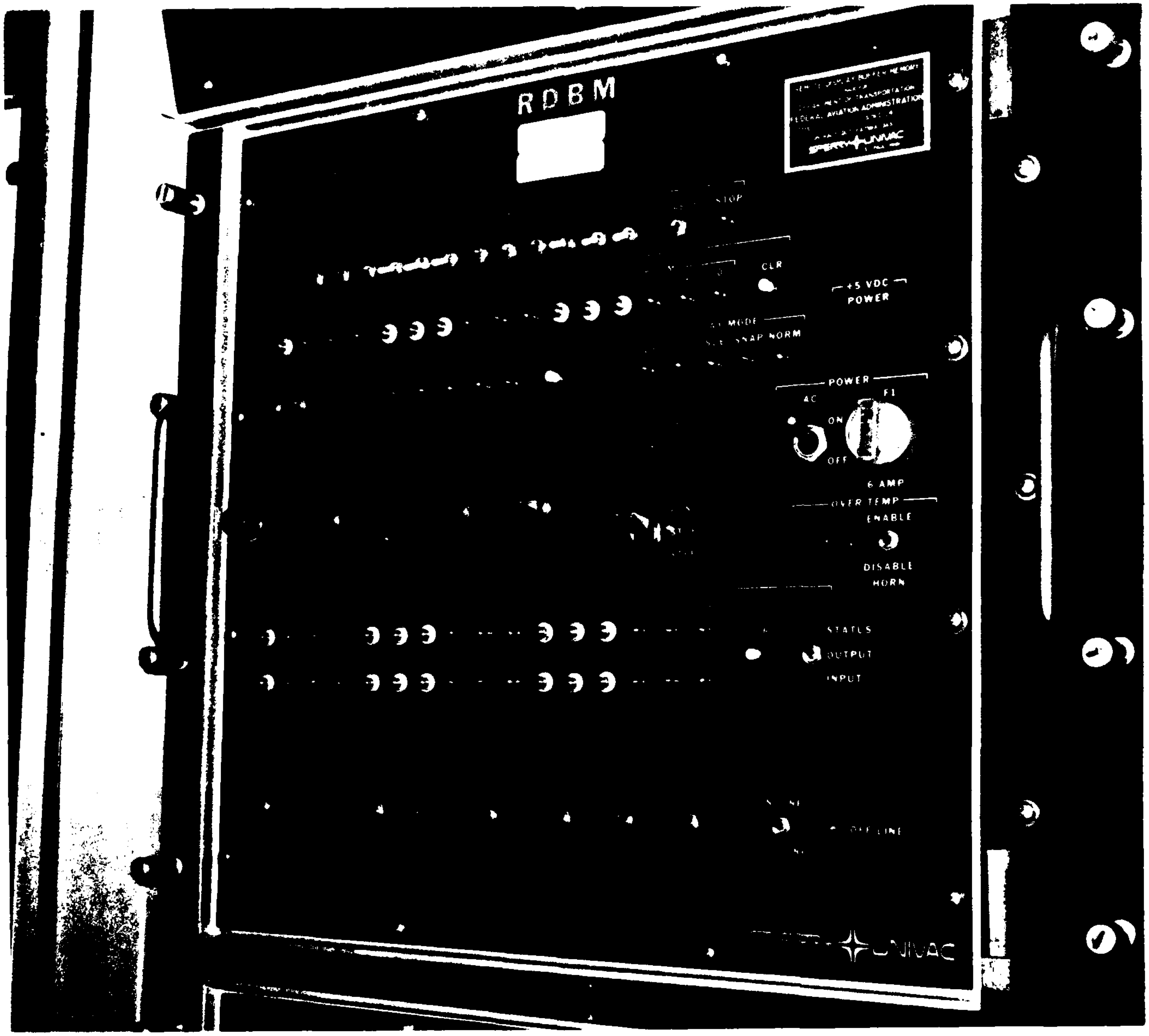

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FIGURE 7. FRONT PANEL OF RDBM

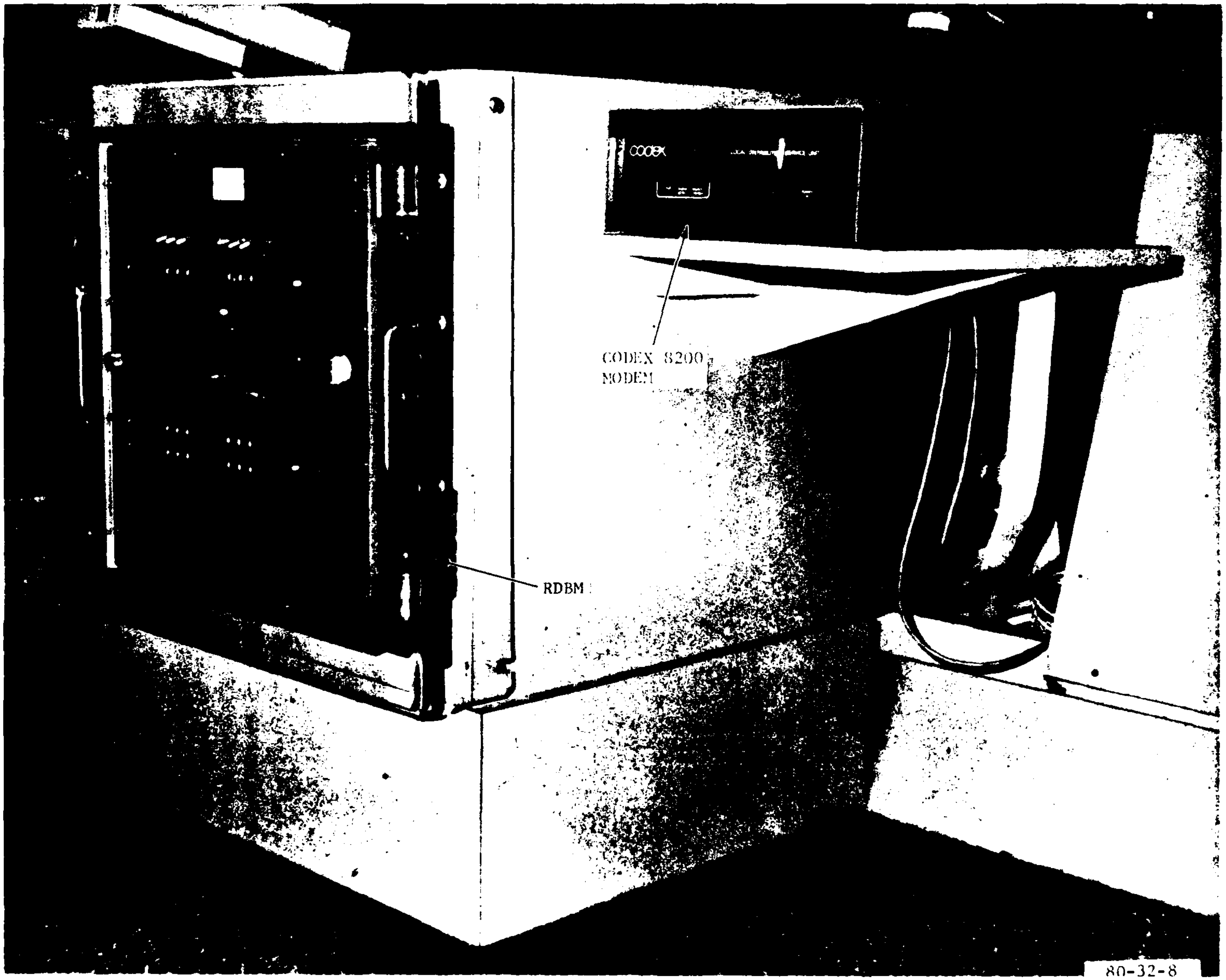

FIGURE 8. CODEX 8200 MODEM AND RDBM USED IN TOWER CAB SYSTEM AT TAMPA

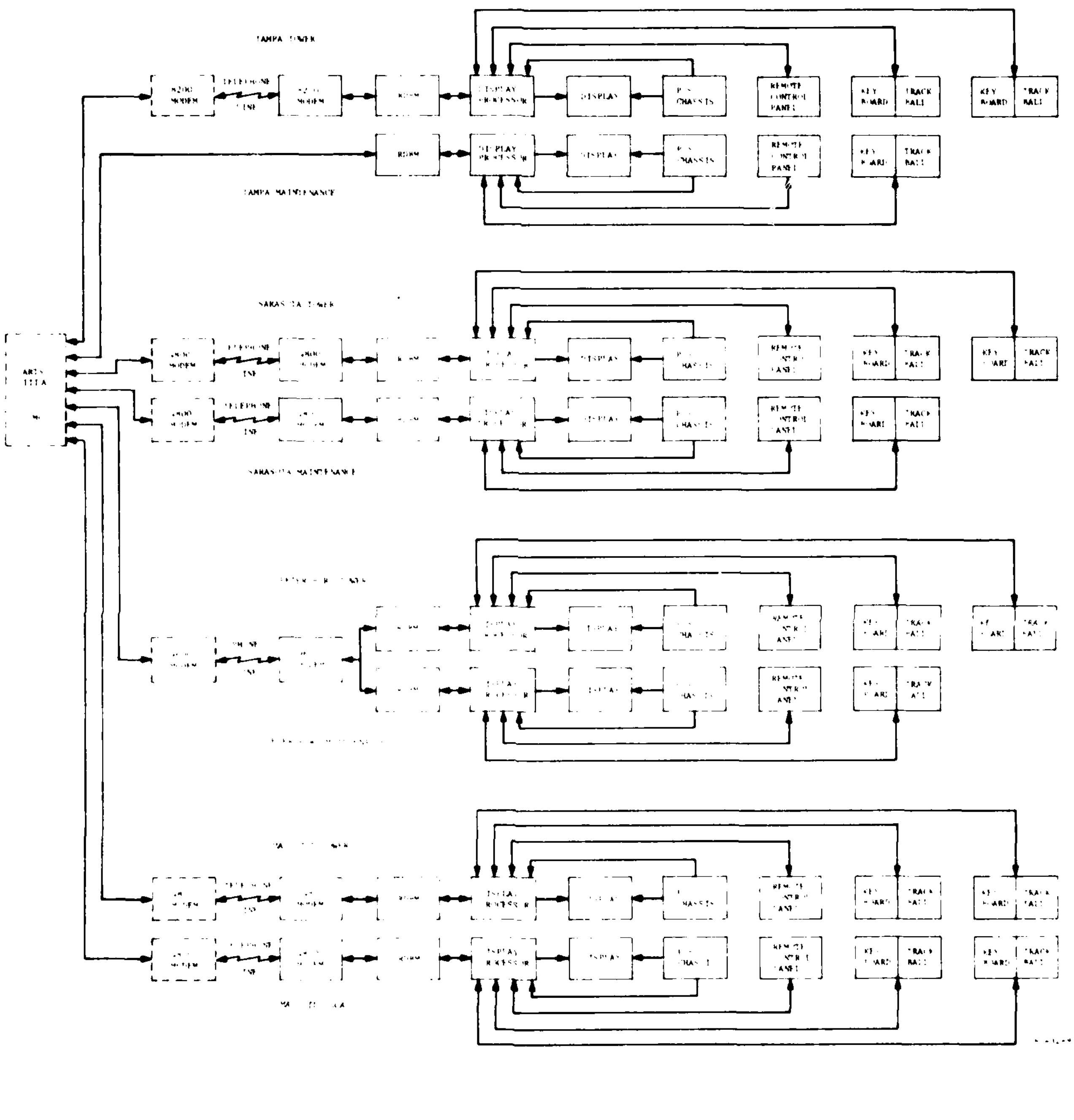

FIGURE 9. ARTS IIIA INTERFACE DIAGRAM

3. The failure requires actual maintenance effort to correct, as opposed to a transient outage which can be reset or master-cleared.

In addition to these general criteria, a failure was charged against the telephone line whenever sufficient degradation occurred to call in the telephone company.

UNIT FAILURE RATES, MTBF's, and MTTR's. The failure rates, MTBF's, and MTTR's for each of the nine types of units comprising a TCDD system were then determined for each of the eight systems evaluated. This was done by determining the total uptime (U), total number of chargeable failures (N), and total repair time (C) for each type of unit per system. These nine types of units, together with the number of units per type per system, are as follows:

Unit Type	No. of Units Per System
Display processor unit	1
Power supply chassis	1
Display	1
Keyboards	2
Remote control panel	1
Trackball	2
Buffer	1
Modem	1
Telephone lines	1

All systems used Codex 4800 modems except for the following:

Tampa - Codex 8200 modem (tower), no modem in maintenance system

St. Petersburg - One Codex 9600 modem for both tower and maintenance system

The values U and C were expressed in terms of unit-hours. In the case of the keyboards and trackballs, which are duplicated, U and C for each of these types of units consist of the sum of the corresponding quantities for each of the two units comprising the unit type for a system.

Since an underlying exponential (constant failure rate) statistical distribution is assumed for the failure and repair rates, the following formulas were used for each type of unit:

$$\text{Failure rate } (\lambda) = \frac{N x 10^6}{U} \text{ failures per million hours}$$

$$\text{MTBF} = U/N \text{ hours}$$

$$\text{MTTR} = C/N \text{ hours}$$

SYSTEM FAILURE RATE, MTBF, AND MTTR. To compute the overall system failure rate, MTBF, and MTTR; a reliability model was employed to determine which of the units must be operational to achieve full and complete equipment functional capability. This model is shown in figure 10. All units are considered to be in a series from a reliability standpoint. The system failure rate, MTBF, and MTTR are expressed as follows:

$$\text{System failure rate } (\lambda_s) = \sum_{i=1}^{9} (\lambda_i)$$

where λ_i represents the failure rate of each of the nine unit types comprising the system.

$$\text{System MTBF} = 10^6 / \lambda_s \text{ hours}$$

$$\text{System MTTR} = \sum_{i=1}^{9} \frac{(\lambda_i \text{ x MTTR})}{\lambda_s} \text{ hours}$$

In addition to the MTBF and MTTR determination considering chargeable hardware and telephone line failures only, this

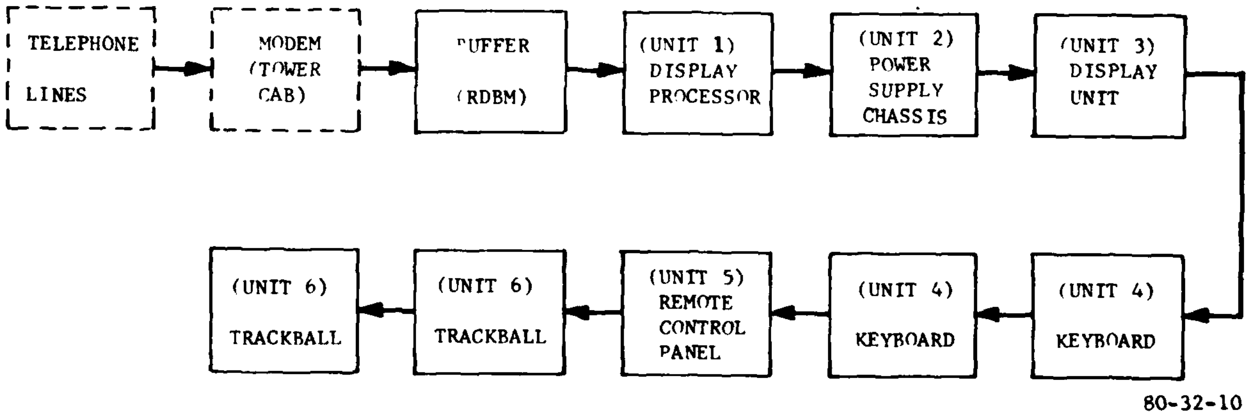

FIGURE 10. TCDD RELIABILITY MODEL

report also discusses all other types of malfunctions which were experienced by the four systems at St. Petersburg and MacDill during the official test period. Finally, summation of problem areas encountered by all eight systems over the entire period of observation is presented.

RESULTS

MTBF AND MTTR SUMMATION (CHARGEABLE FAILURES).

In appendix A, tables A-1 through A-4 show the unit and system chargeable failure summations for the St. Petersburg and MacDill sites during the official test period. Only five chargeable hardware failures occurred, three of which were in the St. Petersburg maintenance system.

Also in appendix A, tables A-5 through A-12 give the unit and system chargeable failure summations for all eight systems from the time each became operational until just prior to the official test. The data collection for the four systems at Tampa and Sarasota was terminated on December 31 since these systems were not officially operable during January and February 1980. These tables show that for the period prior to the official test, comprising approximately 16,000 system-hours of operation, 23 chargeable hardware failures including telephone line outages occurred. This corresponds to an average system MTBF of 653 hours. Excluding the phone line failures, the corresponding MTBF for the pretest period would be 937.5 hours.

Table A-13 shows combined chargeable failure summations for the five operational TCDD systems (four tower systems plus the MacDill GCA system). These values include the official test period for the MacDill and St. Petersburg systems plus the pretest periods for all four sites. The unit (element) type values for the total uptimes, number of chargeable failures, and total repair times are the sums of the corresponding quantities in tables A-1 through A-12. In the case of the modems, only Codex 4800 modems were considered in summating this element type. Twenty chargeable hardware failures (including six telephone line outages) occurred in slightly over 15,000 system-hours of operation corresponding to an average system MTBF of approximately 725 hours with a 2.56-hour MTTR.

Table A-14 provides a similar summation for the three maintenance systems (at Tampa, St. Petersburg, and Sarasota). For these three systems, eight chargeable hardware failures occurred in approximately 6,000 system hours of operation, corresponding to a system MTBF of 705 hours with a 2.37-hour MTTR.

Table 1 shows the combined total chargeable failure summation for all eight systems over the entire period of observation including the official test and the times previous to it. It is seen that 28 chargeable hardware failures occurred in slightly more than 21,000 system-hours of operation, resulting in an overall MTBF of 706.20 hours and an overall MTTR of 2.48 hours. This means that for any TCDD system, including phone lines and modems, one can expect on the average one hardware failure in slightly less than 1 month with an average of 2.48 hours required to repair it and restore the system to operation. Excluding the seven chargeable telephone line failures, the overall system MTBF was 1000.8 hours with an MTTR of 2.86 hours.

The location and nature of the 28 chargeable hardware failures are as follows:

1. Display Processor (Unit 1), Nine Failures

a. Shaky display. Loose printed circuit boards (PCB's).

TABLE 1. OVERALL MTBF AND MTTR SUMMATION

August 25, 1979 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	21,170.05	9	18.5	425.13	2,352.23	2.05
P.S. Chassis (unit 2)	21,183.25	3	5.3	141.62	7,061.08	1.77
Display (unit 3)	21,055.03	4	28.38	189.98	5,263.76	7.09
Keyboard	36,313.15	1	2.25	27.54	36,313.15	2.25
Remote Control Panel (unit 5)	21,188.55	0	--	--	--	--
Trackball	36,318.4	0	--	--	--	--
RDBM	21,182.3	3	6.25	141.63	7,060.7	2.08
Modem (Codex 4800)	13,644.95	1	0.5	73.29	13,644.95	0.5
Telephone Line	16,793.0	7	11.0	416.84	2,399.0	1.57
SYSTEM TOTAL	--	--	72.18	1,416.03	706.20	2.48

-- Indicates no computations made because there were no failures.

b. Parity errors generated when using trackball. Defective A15 (input data interface) PCB.

c. Minus 15-volt short to ground in A22 (deflection generator) PCB.

d. Vectors too short. Defective A21/22 (deflection generator) PCB.

e. Flashing characters. Defective 1A20 (analog character generator) PCB.

f. Bad retrace. Defective A2 (format generator logic A) PCB.

g. Constant fixed off-centering. Defective A16 (control panel logic) PCB.

h. Vectors out of alignment. Defective 1A9 (vector ramp generator) PCB.

i. Range rings not circular. Replaced display processor with spare.

2. Power Supply Chassis (Unit 2), Three Failures

a. Intermittent drop-out of 28-volt power supply (recurring problem).

b. Defective 28-volt power supply. Voltage dropped and was restored when power switch was recycled. Filter capacitor had 10-volt ripple.

c. System down. Pin in cannon plug of power supply chassis was pulled out because of pinched cable.

3. Display (Unit 3), Four Failures

a. Blown 28-volt fuse. Defective focus power supply.

b. Display information shifted off screen toward north. Defective 3A2 deflection amplifier.

c. Display went blank. Defective resistor R25 in 3A6 video unblank amplifier module (Over 34 man-hours of repair and alignment time were required due to lack of accurate up-to-date procedures.)

d. Brightness problem. Defective 3A6 video unblank amplifier module.

4. Keyboard (Unit 4), One Failure

a. Inputted erroneous information when panel lights were turned up full. Heat from lights damaged keyboard code logic PCB 4A2.

5. RDBM, Three Failures

a. Parity Error. Defective A7 (I/O logic) PCB 7156700.

b. Failed performance operational and functional appraisal (POFA) test. Defective programmable read-only memory (PROM) PCB 7163360.

c. Blank display. Defective microregister PCB 7156705.

6. Modem (Codex 4800), One Failure

a. Data link problem. Replaced A1 through A4 PCB's.

7. Telephone Lines, Seven Failures

a. Tower and GCA phone lines at MacDill and maintenance phone line at Sarasota were excessively noisy requiring telephone company repair seven times.

OTHER SYSTEM OUTAGES.

In addition to the overall 28 chargeable hardware failures which were described previously, there were many other system outages which were attributed to other causes. These include transient failures which were corrected by resetting or recycling a switch,

automatic restarts or master clears, untraceable noise on telephone lines, failures due to environmental causes, and failures due to indeterminate causes. These are summarized below for the four systems at St. Petersburg and MacDill for the official test period only (January 7 to February 29, 1980). These outages were not considered to be chargeable.

1. Automatic Restarts - Over 40 automatic RDBM restarts were logged at MacDill Air Force Base between January 4 and February 11. Some were caused by system reconfigurations, some by noise on the telephone lines, and still others by hardware glitches. The causes of the very intermittent restarts are difficult to determine.

2. Display Blanking - Three instances of display blanking occurred at MacDill Air Force Base. One resulted in a 2-hour outage because of an ARTS IIIA communications multiplexer controller outage at Tampa. The second instance involved 6 hours of intermittent periodic display blanking caused by RDBM restarts which were attributed to noisy and marginal telephone lines. The third instance also was due to numerous automatic restarts necessitated by excessive phone line noise.

At St. Petersburg, five instances of display blanking occurred. As at MacDill, all of these occurred during January. One was transitory and was corrected by an RDBM reset. Three others were also transitory and were reset by recycling the power switch of the 9600 modem. The fifth was caused by human error when a plug was inadvertently pulled out during maintenance.

3. Phone Line Problems - Noisy phone lines constituted a recurring problem at MacDill, which uses a Codex 4800 modem in contrast to St. Petersburg, which uses a Codex 9600 modem. The noisy phone lines at MacDill were a factor in the automatic restarts and display blankings.

4. Environmental Problems - Two instances of degraded performance occurred at the St. Petersburg facility as a result of too high an ambient temperature in the maintenance system. In each case, when the room temperature reached 90° F, the degradation manifested itself. In one case, the display was shaky; in the other case, range rings were flattened on the right side. In addition to these two cases observed during the official test, two similar cases were observed at St. Petersburg during the pretest period.

OVERALL GENERAL RESULTS.

1. System Summary Without Telephone Lines - As discussed previously, table 1 provides on overall summary for all eight systems, including the telephone lines. As seen from this table, seven of the 28 chargeable failures occurred in the telephone lines. If these were excluded from consideration, the overall system MTBF would then become 1001 hours with a 2.9-hour MTTR. This would correspond to an average of one chargeable failure occurring every 1.4 months with an average time of 2.9 hours required to restore the system to normal operation.

2. Measured Versus Predicted MTBF - As discussed above, the overall measured MTBF obtained using all collected data for all eight systems (less telephone lines) was 1001 hours. While a corresponding predicted value is not available for comparison, predicted failure rates and MTBF's for various portions of the configuration are available in the contractor's reliablity design plan. Table 2 shows these predicted values compared to the corresponding measured values taken from table 1.

For a TCDD system not including the RDBM, modem, or telephone lines, a measured MTBF of 1,275 hours was obtained. This is lower than the corresponding predicted value of 1,736 hours. The overall measured MTBF for

TABLE 2. PREDICTED VERSUS MEASURED MTBF VALUES

Element Type	Failure Rate In Failures Per Million Hours		MTBF (Hours)	
	Predicted	Measured	Predicted	Measured
Display processor (unit 1)	--	425.13	--	2,352.23
P.S. Chassis (unit 2	--	141.62	--	7,061.08
Display (unit 3)	--	189.98	--	5,263.76
Units 1, 2, and 3 combined	464.525	756.73	2,152.737	1,321.5
Keyboard (unit 4)	77.962	27.54	12,826.762	36,313.25
Panel (unit 5)	7.28	0	137,362.64	--
Trackball (unit 6)	26.285	0	38,044.51	--
TOTAL (units 1 through 6, combined)	576.052	784.27	1,735.954	1,275.07

-- Indicates no computations made because there were no failures.

the display processor, display unit, and power supply chassis, combined, is 1,322 hours, which is lower than the corresponding predicted value of 2,153 hours.

The display processor showed the lowest measured MTBF (2,325 hours) of any of the elements in the system. The telephone lines had the second lowest measured MTBF (2,399 hours).

It is seen from table 2 that the observed MTBF for a system configuration which does not include the RDBM, modem, or telephone lines is 1275 hours versus a corresponding predicted value of 1736 hours.

Table 3 lists recommended MTBF specification values for the production TCDD equipment units and system.

3. Preventive Maintenance - At each of the sites, preventive maintenance activities were performed on a daily, semi-weekly, weekly, monthly, and quarterly basis depending on the nature of the activity. The weekly preventive maintenance activities included special diagnostic POFA tests which exercise the logic in the various elements or units of the system.

4. Codex 4800 Versus 9600 Modems - During most of this evaluation, the St. Petersburg facility was equipped with a Codex 9600 modem and the Sarasota and MacDill facilities with Codex 4800 modems. The Codex 4800 modem was used with an unconditioned telephone line and was sensitive to noise. This situation, especially at MacDill, contributed to such undesirable effects as automatic restarts and jittery displays. On-site personnel observed that the Codex 9600 modem used with a conditioned phone line resulted in better performance than a Codex 4800 modem used with unconditioned phone lines. (Note: Direct performance comparisons using conditioned and unconditioned telephone lines for each modem type were not made).

On February 8, the Codex 4800 modems at MacDill were replaced with Codex 9600 modems using conditioned phone lines.

TABLE 3. RECOMMENDED MTBF SPECIFICATION VALUES FOR TCDD EQUIPMENT AND SYSTEM (HRS)

Display processor	$\geq$ 2,000 (measured)
RDBM	$\geq$ 7,000 (measured)
Power supply	$\geq$ 7,000 (measured)
Display	$\geq$ 5,000 (measured)
Keyboard	$\geq$ 30,000 (measured)
Trackball	$\geq$ 30,000 (predicted)
Remote panel	$\geq$ 100,000 (predicted)
Modems	$\geq$ 10,000 (measured)
System (including all the above items)	$\geq$ 1,000 (measured)

These were operated at 9600- and 4800-bit-per-second rates for experimental purposes. The 9600-bit rate was observed by on-site personnel to have positive benefits among which were: (1) restarts lasted only 2 to 3 seconds; (2) keyboard, trackball, and quick-look entries responded faster; and (3) the tracking range did not fluctuate as it would have at the 4800-bit rate.

Even at a 4800-bit rate, site personnel reported that the Codex 9600 modem would be advantageous because it can accommodate noise which may cause jitter with the Codex 4800 modem.

By the end of this evaluation period, all sites had been equipped with Codex 9600 modems and were awaiting conditioning of the telephone lines.

5. Alignment Problems - At Sarasota, difficulty was encountered in aligning the system after replacing the cathode ray tube (CRT) which had been burned out as a result of a -15-volt short circuit. Several iterative realignments were necessary before satisfactory performance was restored.

Also at Sarasota, after another CRT replacement, alignment and troubleshooting times were excessively long. This was caused by inaccurate obsolete procedures, many of which did not reflect hardware changes.

6. Environmental Problems - On four separate occasions, blinking, shaky targets, or other abnormal display conditions were noted in the St. Petersburg maintenance system where the ambient temperature in the equipment room reached 90° F.

7. Miscellaneous Problems

a. Keyboard Heat Problem - At St. Petersburg, erroneous data were outputted from the keyboard when the panel was at its highest light intensity. The keyboard code logic PCB was damaged by the excessive heat generated. Figure 5 shows this intensity control on the keyboard.

b. Bent Pins - The pins on the display processor PCB's are easily bent if they are not properly aligned before insertion. In addition, bent pin problems occurred in the connector plugs going into the keyboard, trackball, and remote panel. The problem here is that there are plastic rings in the connector plugs which engage the pins before the keying slots make contact, thereby bending the pins. Figure 11 shows a typical connector plug with damaged pins.

c. PCB Potentiometers - Many of the potentiometers mounted on PCB's have adjustments on the bottom side rather than the top edge of the PCB's. An example of this is shown in figure 12. The use of an extender board is required whenever it becomes necessary to align the potentiometer. This involves (1) powering down the equipment, (2) inserting the extender board, (3) restoring power, (4) making the alignment, (5) removing power, (6) removing the extender board, and (7) restoring power. All this increases the MTTR.

8. Replaced PCB's and Modules - The following PCB's and modules were replaced during the period of this reliability and maintainability evaluation:

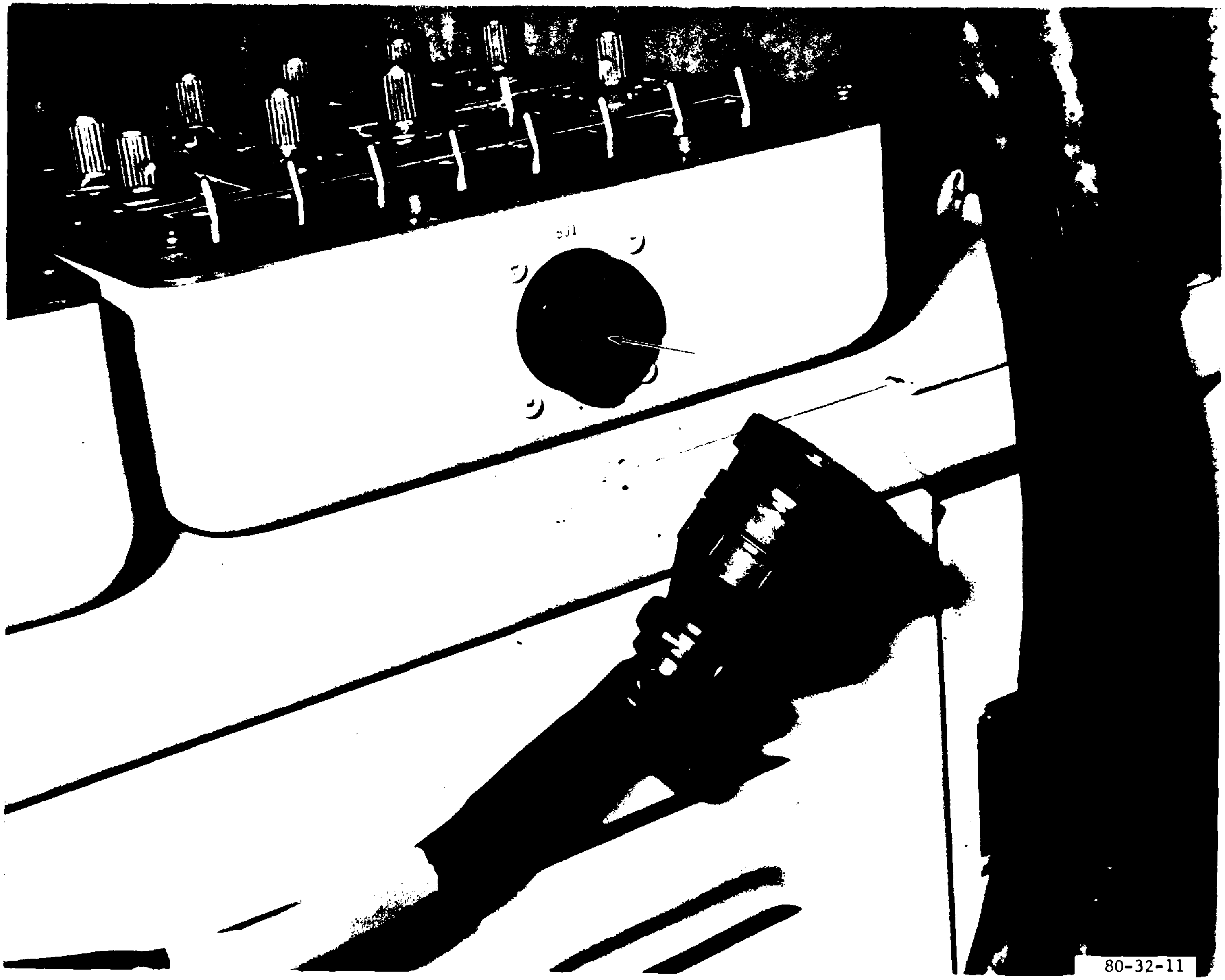

FIGURE 11. TYPICAL CONNECTOR PLUG SHOWING DAMAGED PINS

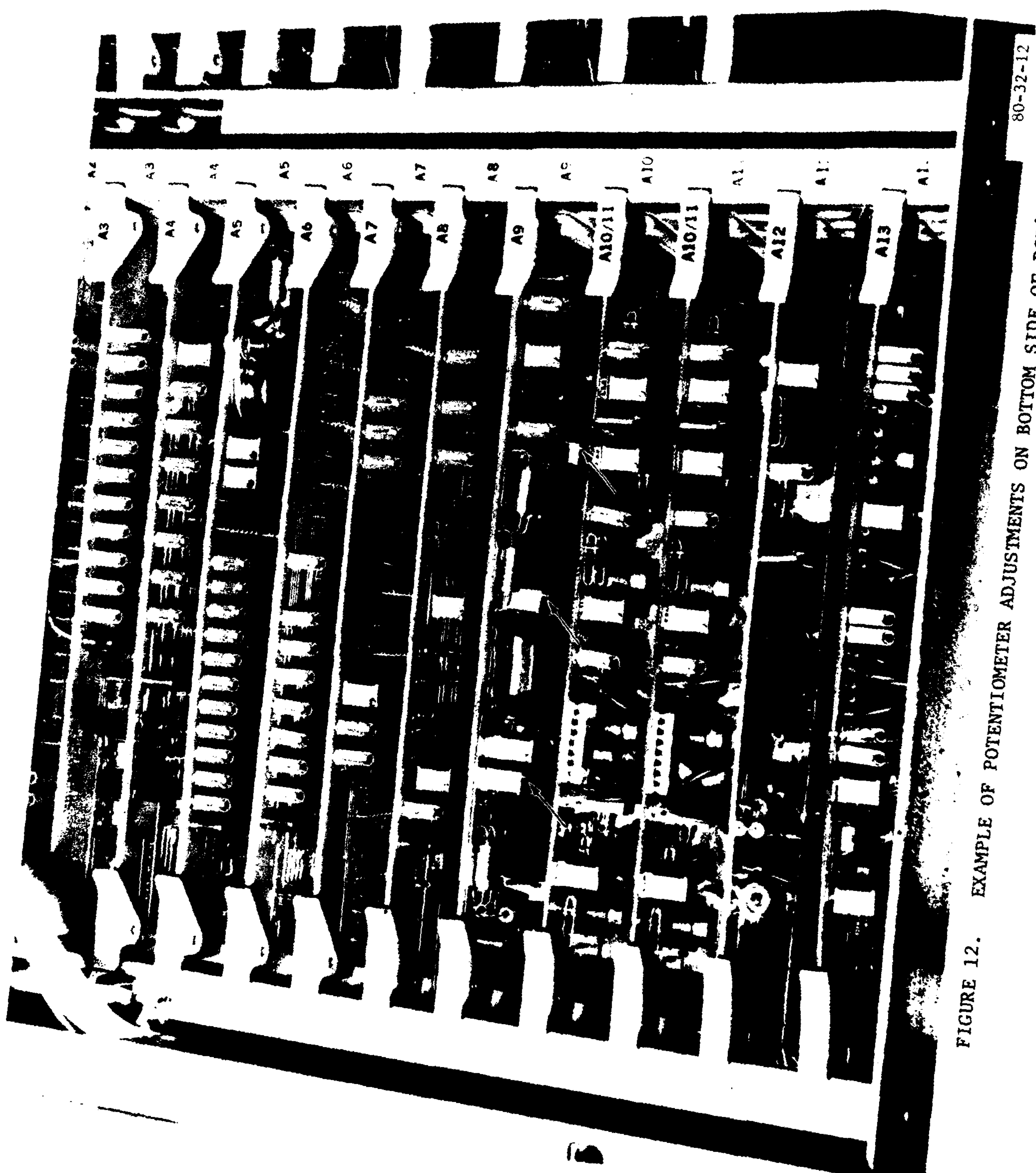

FIGURE 12. EXAMPLE OF POTENTIOMETER ADJUSTMENTS ON BOTTOM SIDE OF PCB's

a. <u>Display Processor</u> -

A2 - Format generator logic A PCB		Part No. 912352	(1)
A9 - Vector ramp generator PCB		Part No. 912544	(1)
A15 - Input data interface PCB		Part No. 912363	(1)
A16 - Control panel logic PCB		Part No. 912364	(1)
A20 - Character generator analog PCB		Part No. 912375	(1)
A22 - Deflection generator PCB		Part No. 912362	(2)
±15-Volt power supply		Part No. SPS-90D	(1)

b. <u>Power Supply Chassis</u> -

28-Volt power supply Lambda LOSW-28 (2)

c. <u>Display Unit</u>

Cathode ray tubes (CRT's)	(2)
3A2 - Deflection amplifier module	(1)
3A6 - Video unblank amplifier module	(2)
3PSI - Focus power supply module	(1)

d. <u>Keyboard</u>

4A2 - Keyboard code logic PCB Part No. 912371 (1)

e. <u>Codex 4800 Modem</u>

A1 - Digital card	Codex	Part No. 33601G1	(1)
A2 - Analog card	Codex	Part No. 33601G2	(1)
A3 - Digital card	Codex	Part No. 33601G3	(1)
A4 - Analog card	Codex	Part No. 33601G4	(1)

f. <u>RDBM</u>

A7 - I/O logic PCB	Part No. 7156700	(1)
A15 - PROM PCB	Part No. 7163360	(1)
A18 - Microregister PCB	Type 7156705	(1)

It has been reported that an RDBM-resident TCDD diagnostic has been developed and is currently being implemented in the Tampa TCDD systems. This diagnostic was not available to maintenance technicians during the test period. The MTTR values for the display subsystem, therefore, may improve as this new diagnostic becomes available.

CONCLUSIONS

1. For a Tower Cab Digital Display (TCDD) system excluding the Remote Display Buffer Memory (RDBM), the modem, or the telephone lines, the measured value was lower than the corresponding predicted value. The overall MTBF for the display processor, display unit, and power supply chassis, combined, was also lower than the corresponding predicted value. The display processor and the telephone lines had the lowest and the second lowest measured MTBF, respectively, of any of the elements in the system.

2. Troubleshooting and alignment times which were excessively long in some cases contributed to the high system MTTR of 2.48 hours. For instance, adjustments of potentiometers mounted on the PCB's are difficult sometimes because the adjusting screws are on the bottom side rather than the top of the potentiometer. An extender board must be used when aligning the potentiometer.

3. Considerable degradation of equipment performance due to noise on the telephone lines was observed by site personnel when a Codex 4800 modem and an unconditioned phone line were used. Use of a Codex 9600 modem with a conditioned phone line has reportedly improved this situation.

4. Degradation of equipment performance in the maintenance room occurred when the ambient room temperature reached 90° F. Normal performance was restored when the temperature dropped to 80° F or 85° F.

5. Erroneous data were outputted from the keyboard when the panel display light intensity was fully illuminated. The keyboard code logic printed circuit board (PCB) failed because of the excessive heat generated.

6. Pins on connector plugs and PCB's are easily bent if not properly aligned before insertion, and the locking rings on the plastic connector plugs break.

RECOMMENDATIONS

1. The mean-time-between-failure (MTBF) values shown in table 3 should be used as the minimum MTBF parameters for inclusion in the production specification.

2. The mean-time-to-repair (MTTR) of over 2 hours for the system is excessive. The production system specification should call for an MTTR of no more than 1 hour.

3. Reasons for the failure of the Tower Cab Digital Display (TCDD) maintenance system when the ambient room temperature is 90°F or greater should be investigated.

4. The following design changes are recommended:

a. Consideration should be given to improving the design of the display processor to increase its MTBF.

b. The keyboard code logic printed circuit board (PCB) 4A2 (Part

No. 912371), which is contained within the keyboard assembly (unit 4), should either be redesigned or possibly relocated so that its performance will not be adversely affected by the heat generated when the panel light is turned up to full intensity. Temperature measurements should be made to help isolate the problem.

c. The PCB's and connector plugs should be examined to determine design improvements which would allow for their easier insertion without bending the pins.

d. Consideration should be given to mounting the potentiometers on the top edge of the PCB's to allow adjustment without using an extender board. This change would save the time required to turn the system off and on when inserting and removing the extender board, thereby reducing the MTTR.

e. Consideration should be given to having all display alignments in the display unit rather than in the display processor as is now done. Alignment of the display unit would be easier and the MTTR reduced.

f. To provide more flexible installation, consideration should be given to increasing the allowable cable length between the RDBM and the display processor from its present limit of 200 feet.

5. Comparative tests under controlled conditions should be made with the TCDD system using Codex 4800 and 9600 modems with both conditioned and unconditioned telephone lines for each type of modem. Based on data obtained from such tests, an appropriate recommendation concerning use of modems and telephone lines could be made.

APPENDIX A

MTBF AND MTTR SUMMATIONS

LIST OF TABLES

TABLE A-1. TOWER SYSTEM
MACDILL OFFICIAL TEST

January 7 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	1296	0	--	--	--	--
P.S. Chassis (unit 2)	1296	0	--	--	--	--
Display (unit 3)	1296	0	--	--	--	--
Keyboard	2592	0	--	--	--	--
Remote Control Panel (unit 5)	1296	0	--	--	--	--
Trackball	2592	0	--	--	--	--
RDBM	1296	0	--	--	--	--
Modem (Codex 4800)	1296	0	--	--	--	--
Telephone Line	1296	0	--	--	--	--
SYSTEM TOTAL	--	0	0	0	--	0

-- Indicates no computations made because there were no failures

TABLE A-2. GCA SYSTEM
MACDILL OFFICIAL TEST

January 7 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	1296	0	--	--	--	--
P.S. Chassis (unit 2)	1296	0	--	--	--	--
Display (unit 3)	1296	0	--	--	--	--
Keyboard	2592	0	--	--	--	--
Remote Control Panel (unit 5)	1296	0	--	--	--	--
Trackball	2592	0	--	--	--	--
RDBM	1295.5	1	0.5	771.90	1295.5	0.5
Modem (Codex 4800)	1296	0	--	--	--	--
Telephone Line	1296	1	1.0	771.60	1296.0	1.0
SYSTEM TOTAL	--	2	--	1543.50	647.9	0.75

-- Indicates no computations made because there were no failures

TABLE A-3. TOWER SYSTEM
ST. PETERSBURG OFFICIAL TEST

January 7 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	1295.5	0	--	--	--	--
P.S. Chassis (unit 2)	1295.5	0	--	--	--	--
Display (unit 3)	1295.5	0	--	--	--	--
Keyboard	2591.0	0	--	--	--	--
Remote Control Panel (unit 5)	1295.5	0	--	--	--	--
Trackball	2591.0	0	--	--	--	--
RDBM	1295.5	0	--	--	--	--
Modem (Codex 9600)	647.75	0	--	--	--	--
Telephone Line	647.75	0	--	--	--	--
SYSTEM TOTAL	--	0	0	0	--	0

-- Indicates no computations made because there were no failures

TABLE A-4. MAINTENANCE SYSTEM
ST. PETERSBURG OFFICIAL TEST

January 7 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	1295.8	0	--	--	--	--
P.S. Chassis (unit 2)	1295.5	1	0.3	771.9	1295.5	0.3
Display (unit 3)	1289.47	1	6.33	775.51	1289.47	6.33
Keyboard	1295.8	0	--	--	--	--
Remote Control Panel (unit 5)	1295.8	0	--	--	--	--
Trackball	1295.8	0	--	--	--	--
RDBM	1294.05	1	1.75	772.77	1294.05	1.75
Modem (Codex 9600)	647.9	0	--	--	--	--
Telephone Line	647.9	0	--	--	--	--
SYSTEM TOTAL	--	3	--	2320.18	431	2.80

-- Indicates no computations made because there were no failures

EXECUTIVE SUMMARY

EQUIPMENT/SYSTEM	OPERATIONAL PARAMETER	EQUIPMENT PARAMETER	PARTS REPLACEMENT PARAMETER	SPECIFICATION PARAMETER
RELIABILITY: (MTBF in hours)				
CATCC-DAIR	661*	971	1304	700
NAVMACS A+	2422	2049	2220	250
CV-3333	23,839	23,839	47,677	2000
ON-143(V)5	16,173	16,173	16,173	---
MAINTAINABILITY: (MTTR/MDT in hours)				
CATCC-DAIR	18/162	18.3/129	17.5/102	0.75
NAVMACS A+	3.4/396	3.7/483	5.5/245	---
CV-3333	16.5/120	13/168	13/168	0.3
ON-143(V)5	3/72	3/72	3/72	---
AVAILABILITY:	EFFECTIVE			
CATCC-DAIR	0.9996	0.525		---
NAVMACS A+	0.9627	0.9697		---
CV-3333	0.9949	0.9965	0.9965	---
ON-143(V)5	0.9988	0.9988	0.9988	---

*"All Data" value is given. No operational failures (greater than 10% loss of capability) encountered.

COMMENTS/RECOMMENDATIONS

CATCC DAIR

(1) It is recommended that ECP's and retrofits be developed to improve the reliability performance of the Control Group Console, OD-146, with emphasis on the Deflection Amplifier and the Power Supply.

(2) It is recommended that the "Human Engineered" keyboards in the OD-58 consoles be replaced with standard typewriter/teletype style keyboards.

NAVMACS A+

(1) Several problems associated with the paper feed rollers of the TT-624 printers were observed; however, because of the age of this model, no design changes are recommended. Use of the available pin-drive tractor-feed with edge-perforated paper to eliminate the roller problem is recommended. Other problems associated with print ribbons indicate that the TT-624 should be replaced by a newer, better design when possible.

(2) Consideration should be given to a mod to the RD-397 air filter, which picks up paper tape chaff, clogs, and causes overheating.

CV-3333

(1) Excellent Reliability Performance.

ON-143(V)5

(1) Extremely Good Reliability Performance.

(2) The baud rate problem -- described in Vol 1, para 2-4.3, and in Vol 2D, para 1-1.2 and para 4-2 -- should be resolved either by re-programming or by other means.

TABLE A-5. TOWER SYSTEM
ST. PETERSBURG (PRETEST)

October 26, 1979 - January 6, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	1748.9	2	3.1	1143.58	874.45	1.55
P.S. Chassis (unit 2)	1752	0	--	--	--	--
Display (unit 3)	1752	0	--	--	--	--
Keyboard	3501.75	1	2.25	285.57	3501.75	2.25
Remote Control Panel (unit 5)	1752	0	--	--	--	--
Trackball	3504	0	--	--	--	--
RDBM	1752	0	--	--	--	--
Modem (Codex 9600)	876	0	--	--	--	--
Telephone Line	876	0	--	--	--	--
SYSTEM TOTAL	--	3	--	1429.15	699.72	1.69

-- Indicates no computations made because there were no failures

TABLE A-6. MAINTENANCE SYSTEM
ST. PETERSBURG (PRETEST)

October 26, 1979 - January 6, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	1749.6	1	2.4	571.56	1749.6	2.4
P.S. Chassis (unit 2)	1752	0	--	--	--	--
Display (unit 3)	1752	0	--	--	--	--
Keyboard	1752	0	--	--	--	--
Remote Control Panel (unit 5)	1752	0	--	--	--	--
Trackball	1752	0	--	--	--	--
RDBM	1752	0	--	--	--	--
Modem (Codex 9600)	876	0	--	--	--	--
Telephone Line	876	0	--	--	--	--
SYSTEM TOTAL	--	1	--	571.56	1749.6	2.4

-- Indicates no computations made because there were no failures

TABLE A-7. TOWER SYSTEM
TAMPA (PRETEST)

December 2 - December 31, 1979

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	714.4	1	0.5	1399.78	714.4	0.5
P.S. Chassis (unit 2)	714.9	0	--	--	--	--
Display (unit 3)	711.2	1	3.7	1406.07	711.2	3.7
Keyboard	1429.8	0	--	--	--	--
Remote Control Panel (unit 5)	714.9	0	--	--	--	--
Trackball	1429.8	0	--	--	--	--
RDBM	714.9	0	--	--	--	--
Modem (Codex 8200)	714.9	0	--	--	--	--
Telephone Line	714.9	0	--	--	--	--
SYSTEM TOTAL	--	2	--	2805.85	356.4	2.1

-- Indicates no computations made because there were no failures

TABLE A-8. MAINTENANCE SYSTEM
TAMPA (PRETEST)

December 2 - December 31, 1979

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	713.9	1	1.0	1400.76	713.9	1.0
P.S. Chassis (unit 2)	714.9	0	0	--	--	--
Display (unit 3)	714.9	0	0	--	--	--
Keyboard	714.9	0	0	--	--	--
Remote Control Panel (unit 5)	714.9	0	0	--	--	--
Trackball	714.9	0	0	--	--	--
RDBM	714.9	0	0	--	--	--
Modem	--	--	--	--	--	--
Telephone Line	--	--	--	--	--	--
SYSTEM TOTAL	--	1	--	1400.76	713.9	1.0

-- Indicates no computations made because there were no failures

TABLE A-9. TOWER SYSTEM
SARASOTA (PRETEST)

September 6 - December 31, 1979

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	2285.95	2	9.5	874.91	1142.98	4.75
P.S. Chassis (unit 2)	2295.45	0	--	--	--	--
Display (unit 3)	2172.95	1	17.35	460.2	2172.95	17.35
Keyboard	4590.9	0	--	--	--	--
Remote Control Panel (unit 5)	2295.45	0	--	--	--	--
Trackball	4590.0	0	--	--	--	--
RDBM	2295.45	0	--	--	--	--
Modem (Codex 4800)	2295.45	0	--	--	--	--
Telephone Line	2295.45	0	--	--	--	--
SYSTEM TOTAL	--	3	--	1335.11	749	9.09

-- Indicates no computations made because there were no failures

TABLE A-10. MAINTENANCE SYSTEM
SARASOTA (PRETEST)

September 6 - December 31, 1979

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	2296	0	--	--	--	--
P.S. Chassis (unit 2)	2293	1	3.0	436.11	2293	3.0
Display (unit 3)	2296	0	--	--	--	--
Keyboard	2296	0	--	--	--	--
Remote Control Panel (unit 5)	2296	0	--	--	--	--
Trackball	2296	0	--	--	--	--
RDBM	2292	1	4.0	436.3	2292	4.0
Modem (Codex 4800)	2296	0	--	--	--	--
Telephone Line	2295	1	1.0	435.73	2295	1.0
SYSTEM TOTAL	--	3	--	1308.14	764.5	2.67

-- Indicates no computations made because there were no failures

TABLE A-11. TOWER SYSTEM
MACDILL (PRETEST)

August 25, 1979 - January 6, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per Million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	3239	1	1.0	308.74	3239	1.0
P.S. Chassis (unit 2)	3238	1	2.0	308.83	3238	2.0
Display (unit 3)	3240	0	--	--	--	--
Keyboard	6477	0	--	--	--	--
Remote Control Panel (unit 5)	3240	0	--	--	--	--
Trackball	6480	0	--	--	--	--
RDBM	3240	0	--	--	--	--
Modem (Codex 4800)	3222	0	--	--	--	--
Telephone Line	2924	4	6.0	1368.00	731.00	1.5
SYSTEM TOTAL		6	--	1985.57	503.63	1.5

NOTE: All failures (except telephone lines) occurred between August 26 and October 11, 1979.

-- Indicates no computations made because there were no failures

TABLE A-12. GCA SYSTEM
MACDILL (PRETEST)

August 25, 1979 - January 6, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	3239	1	1.0	308.74	3239	1.0
P.S. Chassis (unit 2)	3240	0	--	--	--	--
Display (unit 3)	3239	1	1.0	308.74	3239	1.0
Keyboard	6480	0	--	--	--	--
Remote Control Panel (unit 5)	3240	0	--	--	--	--
Trackball	6480	0	--	--	--	--
RDBM	3238	0	--	--	--	--
Modem (Codex 4800)	3239.5	1	0.5	308.69	3239.5	0.5
Telephone Line	2924	1	3.0	342.00	2924	3.0
SYSTEM TOTAL	--	4	--	1268.17	788.54	1.42

NOTE: All failures (except telephone lines) occurred between August 26 and October 11, 1979.

-- Indicates no computations made because there were no failures

TABLE A-13. COMBINED TOWER AND GCA SYSTEMS
ALL SITES

August 25, 1979 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	15,114.75	7	15.1	463.12	2,159.25	2.16
P.S. Chassis (unit 2)	15,127.85	1	2.0	66.10	15,127.85	2.0
Display (unit 3)	15,002.63	3	22.05	199.96	5,000.88	7.35
Keyboard	30,254.45	1	2.25	33.05	30,254.45	2.25
Remote Control Panel (unit 5)	15,129.85	0	--	--	--	--
Trackball	30,259.7	0	--	--	--	--
RDBM	15,129.35	1	0.50	66.097	15,129.35	0.5
Modem (Codex 4800)	11,348.95	1	0.5	88.11	11,348.95	0.5
Telephone Line	12,974.1	6	10.0	462.46	2,162.35	1.67
SYSTEM TOTAL	--	20	--	1,378.9	725.22	2.56

-- Indicates no computations made because there were no failures

TABLE A-14. MAINTENANCE SYSTEMS (COMBINED)
ALL SITES

August 25, 1979 - February 29, 1980

Element Type	Total Uptime (hrs)	No. of Chargeable Failures	Total Repair Time (hrs)	Failure Rate (per million hrs)	MTBF (hr)	MTTR (hr)
Display Processor (unit 1)	6055.3	2	3.4	330.29	3027.6	1.7
P.S. Chassis (unit 2)	6055.4	2	3.3	330.28	3027.7	1.65
Display (unit 3)	6052.4	1	6.33	165.22	6052.4	6.33
Keyboard	6058.7	0	--	--	--	--
Remote Control Panel (unit 5)	6058.7	0	--	--	--	--
Trackball	6058.7	0	--	--	--	--
RDBM	6052.95	2	5.75	330.42	3026.5	2.875
Modem (Codex 4800)	2296*	0	--	--	--	--
Telephone Line	3818.9	1	1.0	261.86	3818.9	1.0
SYSTEM TOTAL	--	8	--	1418.07	705.18	2.37

* Sarasota Pretest period only.

-- Indicates no computations made because there were no failures